AD101 – Nutrient Transformation, Energy Production, and Carbon Credits.

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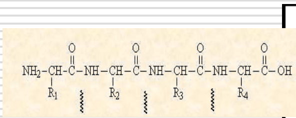
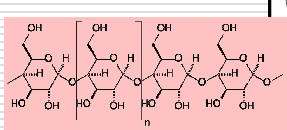
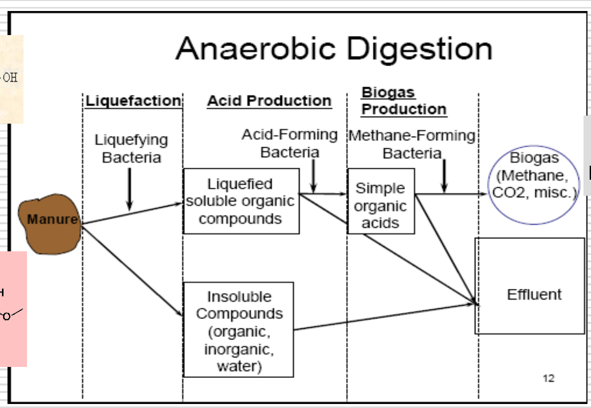
AD101 – What is Anaerobic Digestion?

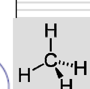


Protein



Carbohydrate





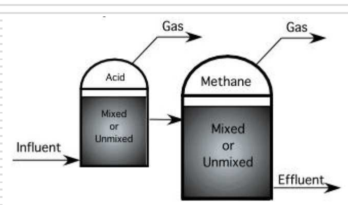
AD101 – Desirable AD Conditions

1. **Anaerobic** bacteria break down or "digest" organic material in the **absence of oxygen** and produce "biogas" as a waste product

2. **Temperature.** Anaerobic bacteria communities can endure temperatures ranging from below freezing to above 135°F (57°C), but they thrive best at temperatures of about 98°F (37°C) (**mesophilic**) and 130°F (54.4°C) (**thermophilic**)
   - For AD operated in the thermophilic range, digestion and biogas production is faster than in the mesophilic range. However, the process is highly sensitive to disturbances, such as changes in feed materials or temperature.
   - On the other hand, the AD operated in the mesophilic range must be larger (to accommodate a longer period of digestion within the reactor) but the process is less sensitive to upset or change in operating regimen.

AD101 – Desirable AD Conditions

- **The AD pH**. In most cases, the pH is self-regulating but bicarbonates are sometimes used to maintain consistent pH. Optimal pH range is between 6.8 to 8.5, i.e. slightly alkaline.
- Acid forming bacteria grow much faster than methane forming bacteria. This can reduce pH to unfavorable pH for methane forming bacteria thus inhibiting the activity of methanagens. This is referred to souring and may result in failure of the AD.



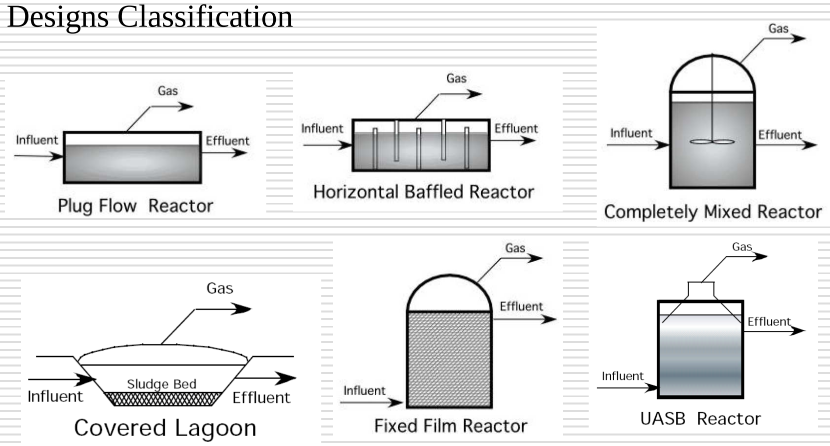
Acid Phased Reactor

AD101 – Types of AD Systems

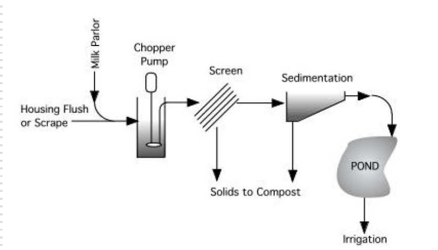
- Classification:
  - Based on: Operational temperature or Design
  - Operational Temperature:
    - Low temperature digestion, commonly referred to mesophilic (mediated by mesophile bacteria) occurs optimally between 37°-41°C or at ambient temperatures between 20°-45°C.
    - High temperature digestion referred to *thermophilic digestion* (mediated by thermophile bacteria) takes place optimally at between 50°-52° and up elevated temperatures up to 70°C.

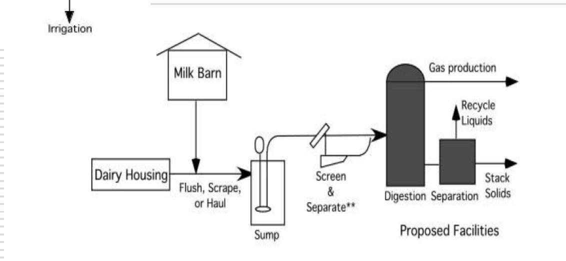
AD101 – Types of AD Systems

Designs Classification

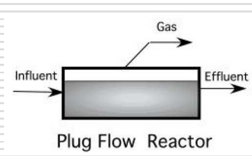


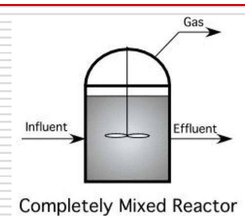
AD101 – Integrating AD into a Livestock Facility

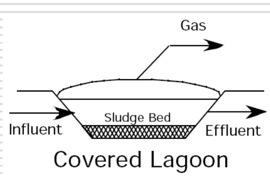




AD101 – What Determines Choice of Design?







AD101 – Manure Collection and Handling System!

- The plug flow digester is best suited for handling manure with a solids content of 11% to 13%
- A complete mix digester operates best with a solids content of 3% to 10%
- Lagoon typically operates on very dilute waste streams of approximately 3%

AD101 – Nutrient (NPK) Transformations

- The process of AD bio-converts organic nutrients into inorganic nutrients
  - Organic-Nitrogen (proteins) converts into ammonium-Nitrogen and biogas
  - Organic-Phosphorus (lipids) is converted to Ortho-Phosphorus and biogas
  - Both Ammonium-N and Ortho-P are both plant available, i.e. AD results in more bioavailable plant nutrients.
  - Implication: Application timing is an issue and should be carefully planned.
- Total Quantities: Total amounts of either nutrient entering the AD process remains the same, i.e. nutrient are conserved during the AD process.
- Potassium (K): Does undergo any transformations during AD of manure or any other organic material.

AD101 – Nutrient Transformations (Case Studies)

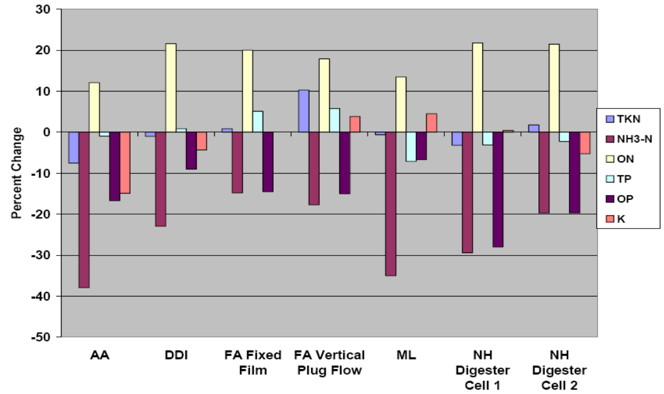


Figure 6. Anaerobic digester influent-effluent percent change in nutrient concentrations for five digesters on commercial dairy farms in New York State (Source: Gooch et al., 2006).

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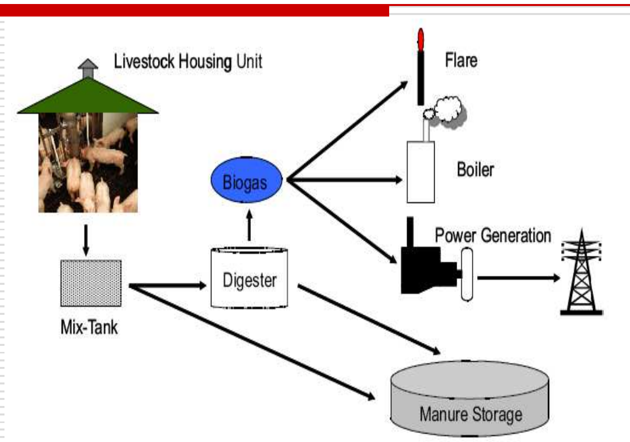
AD101 – Energy Production



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AD101 – Energy Production

- ✓ Depends on the percent of volatile solids (VS) converted to biogas 35 – 45% of TVS)
- ✓ 5.62 ft^3[methane]/lb[VS]
- ✓ 1000Btu/ft^3[methane]
- ✓ 5630Btu/lb[VS] – can be used for heating 100%

- ✓ Electricity Generation Efficiency = 35%
- ✓ 0.58 kWh/lb[VS]
- ✓ 13-16lb[VS]/day
- ✓ 0.58*13 – 0.58*16kWh/day = 7.5 – 9.3 kWh/day = $150 - $186/cow/yr
  - ✓ Minus all the operating costs.

AD101 – Carbon Credits

- The concept of **carbon credits** arose out of increasing awareness of the need to reduce emissions of **greenhouse** gases to combat **global climate change** (warming)

- It was formalized in the **Kyoto Protocol** (international agreement between 169 countries)

- Carbon credits are certificates awarded to countries or businesses for reducing emissions of greenhouses. A credit gives the holder the right to emit one tonne of CO_2. Carbon Credits are **tradable permit** scheme

- For trading purposes, one credit is considered equivalent to one tonne of CO_2 emissions

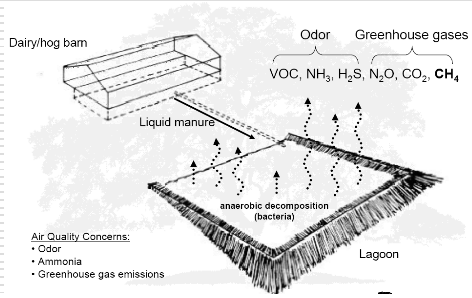
AD101 – Carbon Credits

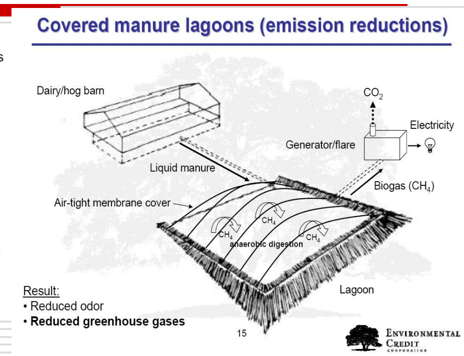
- International treaties such as the Kyoto Protocol set quotas on the amount of the greenhouse gases countries can produce. Countries, in turn, set quotas on the emissions of businesses
- Businesses that are over their quotas must buy carbon credits for their excess emissions, while business below their quotas can sell their remaining credits
- Credits can be exchanged between businesses or bought and sold in international markets at the prevailing market prices. The Chicago Climate Exchange in the US is one such market

AD101 – Carbon Credits Trading

- Assume a certain type of business produces 100,000 tonnes of greenhouse emissions in a year
- Assume that the government allocates a quota of 80,000 tonnes/year to this kind of business
- The business will have two options:
  - Reduce its emissions by 20,000 tonnes or
  - Purchase 20,000 carbon credits to offset the excess emissions
- This business can buy carbon credits on an open market from organizations approved to deal such credits.
- On the flip-side, a company that produces less tonnes of greenhouse gases as it allotted quota would benefit from its effort to reduce those emissions.

AD101 – Carbon Credits: Greenhouse Gases in Livestock Facilities





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AD101 – Carbon Credits (CO_2 equivalents)

Global Warming Potential Global warming potential (GWP) is a relative measure of the amount of heat trapped in the atmosphere by any greenhouse gas. GWP values for different gases are expressed relative to the GWP of the reference gas, carbon dioxide, which is assigned a value of 1.

Global warming potential of greenhouse gases

Gas	GWP
Carbon Dioxide (CO2)	1 *mainly from fossil fuel use*
Methane (CH4)	21 *mainly from ruminant animals and waste*
Nitrous Oxide (N2O)	310 *mainly from agriculture*
Fluorocarbons	140-11,700 *mainly from refrigerants?*
Chlorofluorocarbons	6,500-9,200 *from aluminium production?*
Sulpherhexafluoride	23,900 *mainly from the electricity industry*

Source: IPCC 1996.

1 tonne CH_4 = 21 tonnes CO_2

1 tonne N_2O = 310 tonnes CO_2

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AD101 – Potential Carbon Credits from AD in a Dairy

- Capture CH_4 that would otherwise be fugitive and either use it for energy of just flare it,
- Capture CO_2 or redirect it into a greenhouse, or
- Capture of N_2O – not a major a source.

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AD101 – Carbon Credits

ECC Lagoon Cover Program - Dairy Example

- ~2,000 cow dairy
- Capital cost for individual installation = $130,000
- 10,000 credits (metric tons CO_2e) per site
  - Average 5 metric tons of credits per cow per year
- Current carbon price, 2006 vintage = ~$4.50 per ton (July, 2006)
- Amortize capital over 5 years
- Farmer potential return: $295,336 over 10 years
  - (not including potential value of energy from methane)

Figures may vary based on site specific conditions

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ENVIRONMENTAL CREDIT CORPORATION

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AD101 – Carbon Credits: Is it Real?

News Article — Capital Press, The West's Ag Website

Dairy receives cash for carbon

Hopeful sign of the future, says sustainable-ag leader

12/16/2005 6:00:00 AM

Cookson Beecher
Capital Press Staff Writer

Whatcom County, Wash., dairyman Darryl Vander Haak keeps making history.

Earlier this year, he hosted an open house featuring his farm's $1.2 million anaerobic digester, which turns manure into electricity – the first operating digester of its kind in the state.

Capital Press Photo: Darryl and Judy Vander Haak talk with Gov. Christine Gregoire about their dairy digester during a special trip that Gregoire made to their farm earlier this year to learn more about the technology.

Then just recently, he made history a second time when he and a dairyman from Minnesota received their first payments for carbon credits for reducing greenhouse gas reductions from their farms.

The dairymen were paid for using anaerobic digesters to capture methane, a potent greenhouse gas from manure.

At current prices, the carbon credits produced by the projects were worth more than $26,000.

Together, Vander Haak and the dairy operator in Minnesota were credited with preventing the release of more than 720 tons of methane into the atmosphere. That's equivalent to more than 13,000 metric tons of carbon dioxide.

ECC, which is a member of the Chicago Climate Exchange, worked closely with the farmers to monitor and certify their methane emission reductions. As part of that, they formally registered them with the Chicago Climate Exchange, also known as CCX, in October.

ECC also located buyers for the carbon credits, selling a portion of them to TerraPass, a California company that buys credits on behalf of customers who want to offset the greenhouse gas emissions from their cars.

CCX is the world's first – and North America's only – voluntary, legally binding rules-based greenhouse gas emissions allowance trading system.

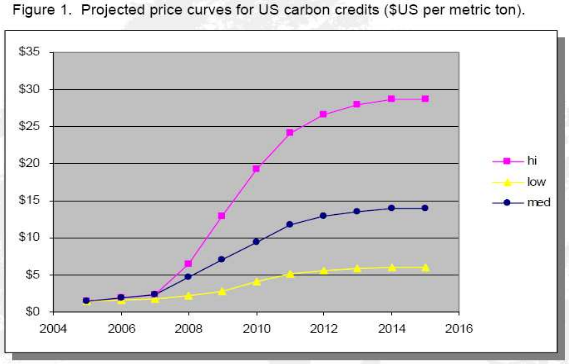
Gov. Christine Gregoire, who visited the Vander Haak dairy this past June, was pleased to learn about the exchange of cash for carbon credits, saying that Washington dairy farmers are on the cutting edge of the emerging farm-energy economy.

"I believe digesters are a promising technology for our dairy farmers, providing multiple new revenue sources, keeping farmers on the farm, and cleaning up our air and water," she said.

Jay Gordon, executive director of the Washington State Farm Dairy Federation, was equally pleased, especially because payments for carbon credits represent an additional revenue stream from the digester.

AD101 – Carbon Credits: The Future Looks Good!

Figure 1. Projected price curves for US carbon credits ($US per metric ton).



Sources: Carbon Finance, August 2004; EIA/DOE 2004. Analysis of S. 1844, the Clear Skies Act of 2003; S. 843, the Clean Air Planning Act of 2003; and S. 366, the Clean Power Act of 2003. Energy Information Administration, USDOE, SR/OIAF/2004-05, May 2004; EIA/DOE 2005. Impacts of Modeled Recommendations of the National Commission on Energy Policy. Energy Information Administration, USDOE, SR/OIAF/2005-02, April 2005; AEP 2004. An assessment of AEP's actions to mitigate the economic impacts of emissions policies. American Electric Power, August 31 2004

Thank You!

Questions?